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Systems Engineering Processes at NASA/SR-71 Pratt & Whitney J58 Engine

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This summer I was given several opportunities at NASA's Dryden Flight Research Center (DFRC). The first opportunity was given to me by a Senior Propulsion Engineer, Kurt Kloesel, to work in a specialized engineering discipline. My task was to research the Pratt & Whitney J58 engine that was used on the SR-71 Blackbird. I entered the data I collected into engine modeling software programs in order to receive certain outputs, such as net thrust. I also had to take a "crash course" in propulsion in order to better understand the research I was performing. To facilitate my understanding of propulsion principals and formulas, I worked many problems out of thermodynamics and propulsion textbooks and entered the given values of various situations into the modeling software.

In my research, I noticed that in every NASA program or project there are multiple levels and subsystems that concentrate on various facets, not just one discipline. Eventually all the pieces will need to be integrated together to make the final product. Creating the final product involves a very complex series of events and, unfortunately, complexity creates issues. So in addition to working on a propulsion task, I was also given the opportunity to work in the Systems Engineering (SE) Branch. SE deals with an entire program or project. Because SE looks at the big picture, systems engineers can develop procedural requirements and technical processes that allow integration to run smoothly. To make following NASA Agency and DFRC procedures simpler at Dryden, the Systems Engineering Branch, decided to create a webpage dedicated to SE. My task was to design the layout of the webpage using Microsoft PowerPoint.

In addition to researching SE processes, my mentor, Cyndi Mangus, required me to create a five-year plan for myself. I essentially had to 'system engineer' my life. This included outlining my personal, financial, and career goals, creating a timeline of events leading to my goals, and ultimately creating a five-year resume.

I was given the unique opportunity to research and understand the engine of a truly historic stealth plane. The engine was the Pratt & Whitney J58 on the SR-71 Blackbird. The J58 is a hybrid jet engine, which means is that at lower speeds it operates as a turbojet, but as the plane accelerates to Mach 3 the engine converts into a ramjet.

Specifically, my task was to find the different parameters of the engine, such as the compression ratio, the burner temperature, etc. With these values I was able to use them as inputs for the Graphical Engine Cycle Analysis Tool (GECAT) software. As can be seen in Figure -1, parameters had to be entered for the different stages of an engine in order to receive the end values.

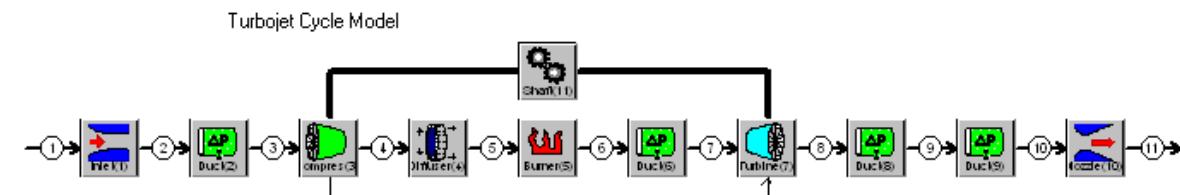


Figure-1

Even though the research I performed with the propulsion branch was very interesting and exciting, I began to understand that a project must be viewed holistically, and there are other areas that need to be taken into consideration by the individual subsystems. With the SE Webpage Project I was able to learn about how all the branches and their technical and safety requirements must be viewed as a single unit for the project to succeed. More specifically I was required to edit each page of the webpage's PowerPoint template (Figure-2) to ensure that the correct information will be provided. This mostly consisted of removing unnecessary information and updating the review requirements using a NASA SE document called the NPR 7123.1A. The main focus of the SE Webpage is the entry and exit criteria of the multiple reviews that a project must undergo at DFRC. Each of the lifecycle reviews are described as followsⁱ:

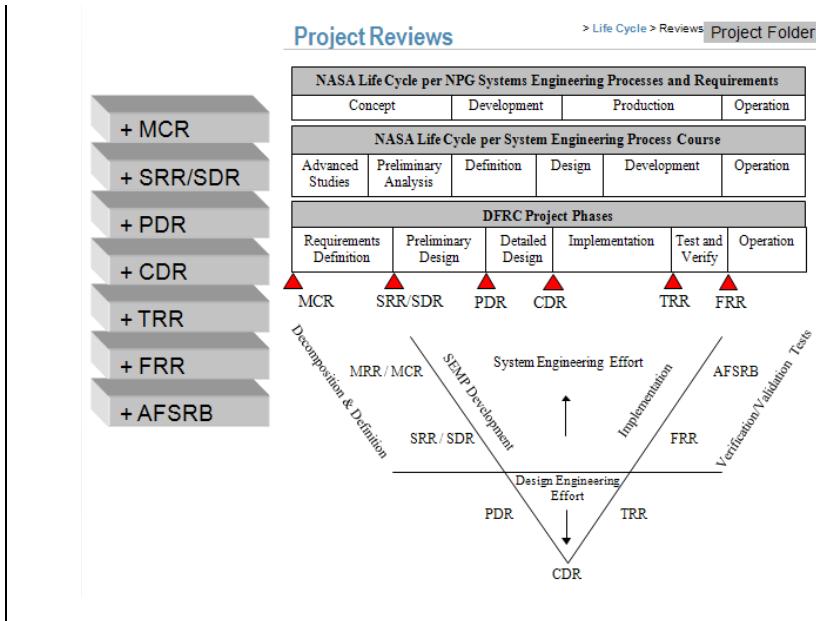


Figure-2

The Mission Concept Review (MCR) is the first review that must take place. It affirms the mission need and examines the proposed mission's objectives and the concept for meeting those objectives. A successful MCR confirms that the proposed mission meets the stakeholders' needs and presents enough merit to move onto the concept development phase. Often research such as the SR-71 propulsion research, which I was involved in, may lead to a MCR, if DFRC wants to evolve this research into a project.

Next is the System Requirement Review (SRR). The SRR examines the functional and performance requirements defined for the system and the preliminary project plan and ensures that the requirements and selected concept will satisfy the mission. The end result of an SRR is to finalize the project requirements in order to proceed with proposal request preparations for project implementation.

After the SRR is the Preliminary Design Review (PDR). The PDR demonstrates that the preliminary design meets all system requirements with acceptable risk and within the cost and schedule constraints. The successful completion of a PDR authorizes the project to proceed into implementation and toward final design.

Afterwards is the Critical Design Review (CDR). The CDR is to demonstrate that the design is ready to proceed with full scale fabrication, assembly, integration, and testing.

The next lifecycle review is the Test Readiness Review (TRR). A TRR ensures that the test article, test facility, support personnel, and test procedures are ready for testing and data acquisition, reduction, and control. The outcome of a TRR is that test and safety engineers have certified that preparations are complete, and that the project manager has authorized formal test initiation.

The following review is the Flight Readiness Review (FRR). The FRR examines tests, demonstrations, analyses, and audits that determine the project's readiness for a safe and successful flight and for subsequent flight operations. The FRR may in some cases initiate system operations.

The last review is unique to DFRC because of the nature of the testing done at the center. The Airworthiness and Flight Safety Review Board (AFSRB) is tasked with performing certain review processes in order to ensure the flight safety of all projects conducted at DFRC.

In addition to understanding how SE is applied to NASA projects, I had to apply SE processes to my life. My mentor gave me the task of creating a five-year plan for myself. The first step was to outline my personal, financial, and careers goals. Once this was done, I had to put all of these goals on a timeline with steps for reaching them. Because I have many future options I had to conduct trade studies on all of them, which is also an essential part of systems engineering. For the trade studies, I researched in great detail graduate schools and different jobs within the commercial industry, and also within NASA. This information helped me narrow the spectrum of choices and enabled me to create a Gantt chart for the next five years of my life.

¹ All information on lifecycle reviews was taken from the NASA Systems Engineering Handbook – NASA/SP-2007-6105 Rev1

Impact of the MUST Internship on My Career Goals

My internship began with me having to assess myself and my goals. At the time my goals were very vague. They consisted of attaining bachelor's and master's degrees in aeronautics and aerospace and then getting a job. My mentor showed me that I needed to replace my vague list with specific goals. I needed to system engineer a plan for myself.

The first step to making this plan was to know what I enjoy doing as a career as well as in my personal life. I had a small idea of what I wanted to do in my career based on the classes I have taken thus far, but it was not enough to base my plan on. Fortunately, I was able to take tours of different projects, planes, and departments to help me decide what I am interested in. I had the unique opportunities of touring the Ikhana (an unmanned aircraft used for fire detection/surveillance missions), the Stratospheric Observatory for Infrared Astronomy (a telescope mounted on a B-747), the X-48B (an unmanned blended wing body aircraft), and Global Hawk (an unmanned surveillance aircraft). In addition, I worked on a propulsion project so I could learn about a specific discipline.

These experiences coupled with my class experiences allowed me to narrow my areas of interest to flow dynamics and propulsion. From there I researched jobs that would allow me to work in either of those fields while also allowing me to pursue my personal goals. These jobs range from a propulsion engineer to an automotive aerodynamicist, but as I move forward in my undergraduate studies this range will again narrow.

I then looked at graduate schools with highly rated aerospace programs. I researched in depth the research that the professors perform as well as the capabilities of the research facilities. With all the data I collected, I will be able to wisely choose a graduate school that will accommodate my career and personal goals. The next step in my plan is to work towards meeting the exit criteria of my undergraduate program and the entry criteria of my graduate university of choice.